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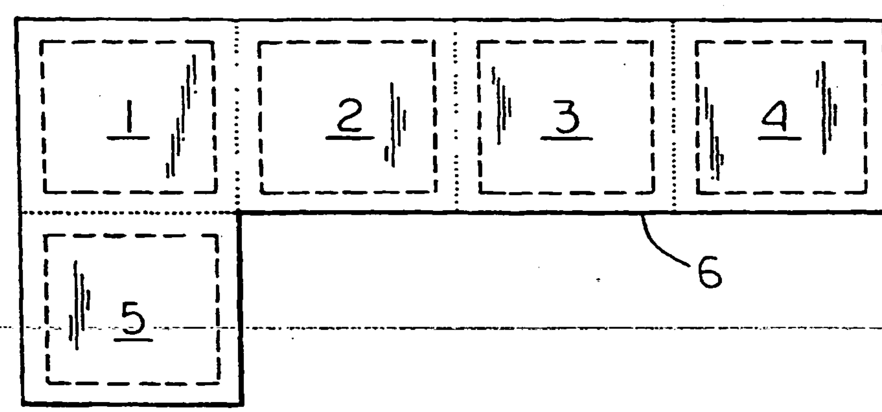
(54) Title: EVACUATED INSULATION ARTICLE HAVING A PLURALITY OF POROUS INNER SUPPORTS



(57) Abstract: An evacuated insulation article comprising at least two rigid porous side supports enclosed in a single deformable evacuated receptacle, wherein at least two adjacent side supports form a corner having an angle of less than 150 degrees, and the supports are shaped or are spaced apart sufficiently within the receptacle before evacuation so that the supports form the corner upon the receptacle being evacuated or the corner is formed after evacuation by bending the receptacle between the supports, without causing tears or breaks in the receptacle.

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EVACUATED INSULATION ARTICLE HAVING A PLURALITY OF POROUS INNER SUPPORTS

Background of the Invention

This invention relates generally to vacuum insulation articles, and particularly to such articles that comprise an evacuated rigid porous material that is enclosed in a sealed deformable receptacle, such as a film or foil pouch.

Vacuum insulation articles typically comprise a sealed container from which gas molecules have been evacuated under reduced pressure. For example, the sealed container may be a deformable receptacle, such as a flexible film pouch, having a frame or porous supporting object inside of it to maintain a certain shape or volume when the pouch is evacuated. In one embodiment, the article may comprise an open-cell microcellular foam core which is enclosed in a sealed deformable receptacle, as described in US Patent No. (USP)5,674,916.

Such articles have a relatively high thermal resistance and are useful in a variety of applications such as, for example, automotive, household appliance, and medical shipping applications wherein high insulation efficiency at a relatively small weight and thickness is desirable. However, if the application requires a number of panels which abut each other at their edges, such as to substantially enclose a temperature-sensitive article in a box-shaped insulation article, or to use a number of smaller supports to make a relatively large insulating panel, there may be significant heat transmission at joints where the panels contact each other, resulting in reduced insulation efficiency.

Summary of the Invention

A first aspect of this invention is an evacuated insulation article comprising at least two rigid porous side supports enclosed in a single deformable evacuated receptacle. In this embodiment, at least two adjacent side supports form a corner having an angle of less than (<) 150 degrees (150°), and the supports are shaped or are spaced apart sufficiently within the receptacle before evacuation so that the supports form the corner upon the

receptacle being evacuated or the corner is formed after evacuation by bending the receptacle between the supports, without causing tears or breaks in the receptacle.

A second aspect of this invention is an evacuated insulation article having a rigid porous side support therein, the support having at least one flexible groove which bends and forms a corner having an angle of < 150°. This article comprises at least one rigid porous support enclosed in a single deformable evacuated receptacle. The support has at least (greater than or equal to or ≥) one groove of a suitable size and shape to cause the receptacle to assume a desired shape upon being evacuated, or to be deformable into the desired shape after evacuation, without causing tears or breaks in the receptacle.

A third aspect of this invention is an evacuated insulation article having at least two rigid porous side supports therein with shaped edges which form joints. The supports are enclosed in a single deformable evacuated receptacle, wherein the edges of two adjacent supports define a joint where they contact each other, and wherein the length of the joint is at least 120 percent (%) of the thickness of the supports.

A fourth aspect of this invention is a multi-sided evacuated insulation article comprised of (≥) three evacuated receptacles, each of which is in contact with ≥ one other receptacle, each of which contains a rigid porous side support having a shaped edge, wherein the edges of the receptacles define a joint where they contact each other, and the supports are shaped along their edges so that the length of the joint is at least 120 % of the thickness of the supports.

It has been discovered that the articles of the first and second aspects provide a means to make a vacuum insulation article in the shape of an enclosure, which will protect an object from exposure to heat or cold from more than one direction, without a gap at a joint which forms a corner of the enclosure which would otherwise permit air or radiation to pass through the joint. Since the receptacle containing the support may be evacuated in a single step, doing so may provide a more efficient means of making a multi-sided enclosure article than if the article was assembled entirely from separately-made vacuum insulation panels.

The articles of the third and fourth aspects of the invention provide a means to make relatively large vacuum insulation articles from a series of smaller porous rigid supports,

yet prevent a substantial amount of heat loss through the panel. These and other advantages of the invention will be apparent from the description which follows.

Brief Description of the Drawings

Figures (FIGS.) 1A and 1B show an evacuated insulation article made of an evacuated receptacle having five rigid porous supports enclosed therein.

FIGS. 2A and 2B show an evacuated insulation article made of an evacuated receptacle having twelve rigid porous supports enclosed therein.

FIGS. 3A and 3B show a multi-sided insulation article having four rigid porous supports enclosed in it.

FIG. 4 shows a rigid porous support having three grooves in it.

FIGS. 5A-5F illustrate six different joint configurations for abutting rigid porous supports.

Detailed Description of the Preferred Embodiments

Unless otherwise stated, all ranges include both endpoints used to establish the range.

In the article of the first aspect of the invention, ≥ two of the supports are shaped or are spaced apart sufficiently within the receptacle before evacuation so that the receptacle either assumes the desired shape upon being evacuated or is deformable into the desired shape after evacuation without causing tears or breaks in the receptacle. FIG. 1A illustrates an embodiment of the first aspect of the invention. The figure shows an evacuated receptacle having five supports 1, 2, 3, 4, and 5 spaced apart sufficiently before the receptacle 6 is evacuated, so that either during evacuation the supports cause the receptacle to automatically be drawn up into the shape of a box shown in FIG. 1B having an open top, or after evacuation, the receptacle may be folded into the shape of a box. However, a number of

other configurations may also be employed. For example, as the number of supports increases, the article may approach the shape of a cylinder, as illustrated in FIGS. 2A and 2B, which show an article having 12 supports. If an article which is flat after evacuation but which may be later folded into the shape of the receptacle is desired, it may be necessary to use wires or weights to restrain the receptacle during the evacuation process to prevent the article from folding up as evacuation proceeds. In another embodiment, the supports have ≥ two sides which form an angle therebetween of other than 90°, as illustrated in FIG. 3A, so that the supports 31, 32, 33, and 34 fit more closely together when the evacuated panel is folded, as illustrated in FIG. 3B.

In the second aspect of the invention, a single support having at least one groove in it of a suitable size and shape to cause the receptacle to assume the desired shape upon being evacuated, or to be deformable into the desired shape after evacuation without causing tears or breaks in the receptacle. FIG. 4 shows a single piece of foam 40 having three such grooves 41 in it, dividing the foam into sections 42. When the foam is placed in a receptacle and the receptacle is evacuated, the receptacle will tend to pull the porous support along the grooves and draw up into the desired shape. In this embodiment, the porous support is a polymeric foam which may be sufficiently flexible to permit it to bend along the joint without breaking when it is folded.

In the third aspect of the invention, ≥ two rigid porous supports are enclosed in a single deformable evacuated receptacle, the edges of two adjacent supports define a joint where they contact each other, and the length of the joint is ≥ 120 % of the thickness of the supports. FIGS. 5A-5F illustrate several different types of joint configurations of abutting supports used to make a larger support. These figures show, respectively, a dovetail joint, a tongue-and-groove joint, a cove joint, an angle joint, a lap joint, and a v-groove joint. The length of a joint is its path length from one side of the support to the other, in a direction parallel to a plane which is perpendicular to the surface of the side of the support. As illustrated in FIG. 5, the path lengths of the joints are illustrated as paths AB, CD, EF, GH, IJ, and KL. It is believed, without intending to be bound thereby, that these types of joints provide an elongated heat flow path that slows the flow of heat from one side of the panel to the other through the joint. These joints improve the insulating performance of multiple

porous support pieces used to prepare a single vacuum panel and of multiple vacuum panels joined together.

In the fourth aspect of the invention, the multi-sided vacuum article comprises ≥ three evacuated insulation panels in contact with each other along an edge of each panel, each panel having a rigid porous support enclosed in a single deformable receptacle, wherein the edges of two panels define a joint where they contact each other, and the supports are shaped along their edges so that the length of the joint is ≥ 120 % of the thickness, T, of the supports. The panel supports have edges shaped so that when the panels are prepared and placed in contact with each other, their edges define a joint as illustrated in FIGS. 5A-5F. A primary advantage of joining multiple panels in this way is an increase in tortuous path length for air and heat flow from one side of a panel to the another side of the same panel. In addition, an increase in contact area between panels favors forming an air-tight and heat-tight seal between panels, thus improving thermal resistance of the multiple panel system.

The porous support may be any suitable rigid material having a thickness ≥ 5 millimeters (mm) which, in a vacuum environment, has an R-value ≥ 2.5 °F.hr.ft^2/BTU (53 milliwatts per meter-degree Kelvin (mW/mK)). "Rigid", as used herein, means that the support does not collapse when evacuated and, after evacuation, has a density in the range of from 16 to 250 kilograms per cubic meter (kg/m^3). The thickness of the porous support is preferably ≥ 7 mm, more preferably ≥ 10 mm, most preferably ≥ 15 mm.

Examples of suitable porous supports include polystyrene foam; other open cell thermoplastic foams such as polypropylene, preferably the polypropylene foam described in USP 5,527,573, the teachings of which are hereby incorporated by reference; polycarbonate foams; thermoset foams, such as polyurethane foam, epoxy-resin foams, formaldehyde foams, phenolic foams, isocyanurate foams; or any other polymeric material, either thermoplastic or thermoset with a relatively rigid open cell structure that prevents complete collapse of the receptacle during evacuation of gases from the receptacle. Other materials generally useful as porous materials include silica or other powder filled supports if the loose powder is sufficiently compressed or bonded in any way to form a unified structure, which is then scored to produce a smooth surface after evacuation. Additionally, this invention can be applied to compressed fiberglass or glass bead supports, if the core is sufficiently solid to allow scoring

of the surface, and to aerogel and xerogel filler materials, which exhibit shrinkage upon encapsulation in vacuum insulation articles. Preferred porous materials are polystyrene and polypropylene foams, with polystyrene foams being especially preferred.

The support material preferably comprises an alkenyl aromatic polymer foam. Suitable alkenyl aromatic polymer materials include alkenyl aromatic homopolymers and copolymers of alkenyl aromatic compounds and copolymerizable ethylenically unsaturated comonomers. The alkenyl aromatic polymer material may further include minor proportions of non-alkenyl aromatic polymers. The alkenyl aromatic polymer material may be comprised solely of ≥ one alkenyl aromatic homopolymers, ≥ one alkenyl aromatic copolymers, a blend of ≥ one of each of alkenyl aromatic homopolymers and copolymers, or blends of any of the foregoing with a non-alkenyl aromatic polymer. Regardless of composition, the alkenyl aromatic polymer material comprises greater than (>) 50, preferably > 70 weight percent (wt%) alkenyl aromatic monomeric units, based on total alkenyl aromatic polymer weight. Most preferably, the alkenyl aromatic polymer material is comprised entirely of alkenyl aromatic monomeric units.

Suitable alkenyl aromatic polymers include those derived from alkenyl aromatic compounds such as styrene, alphamethylstyrene, ethylstyrene, vinyl benzene, vinyl toluene, chlorostyrene, and bromostyrene. A preferred alkenyl aromatic polymer is polystyrene. Minor amounts of monoethylenically unsaturated compounds, such as C_{2-6} (2 to 6 Carbon atoms) alkyl acids and esters, ionomeric derivatives, and C_{4-6} dienes, may be copolymerized with alkenyl aromatic compounds. Examples of copolymerizable compounds include acrylic acid, methacrylic acid, ethacrylic acid, maleic acid, itaconic acid, acrylonitrile, maleic anhydride, methyl acrylate, ethyl acrylate, isobutyl acrylate, n-butyl acrylate, methyl methacrylate, vinyl acetate and butadiene. Preferred foams comprise substantially (i.e., > 70 wt%) and most preferably entirely of polystyrene. Preferably, the alkenyl aromatic polymer foam is free of rubber content such as C_{4-6} dienes and thermoset polymer content such as polyisocyanurate or polyurethane.

A useful microcellular foam is an extruded, open-cell alkenyl aromatic polymer foam. The open-cell foam comprises an alkenyl aromatic polymer material comprising > 50 wt% alkenyl aromatic monomeric units and preferably ≥ about 70 wt% alkenyl aromatic

monomeric units. The foam may be comprised entirely of polystyrene. The foam preferably has an open cell content of ≥ 50 %, more preferably ≥ 90 %, and most preferably ≥ 95 % (ASTM D-2856). Microcellular foam methods of manufacture are seen below and in WO 96/34038, the teachings of which are hereby incorporated herein by reference.

The extruded, open-cell microcellular foam may be prepared by heating a thermoplastic material to form a plasticized or melt polymer material, incorporating therein a blowing agent to form a foamable gel, and extruding the gel through a die to form the foam product. Prior to mixing with the blowing agent, the polymer material is heated to a temperature at or above its glass transition temperature or melting point. The blowing agent may be incorporated or mixed into the melt polymer material by any means known in the art such as with an extruder, mixer, blender, or the like. The blowing agent is mixed with the melt polymer material at an elevated pressure sufficient to prevent substantial expansion of the melt polymer material and to generally disperse the blowing agent homogeneously therein. The amount of blowing agent incorporated is from about 0.06 to about 0.17 gram-moles per 100 grams of polymer (g-m/100g). A nucleating agent such as talc is blended in the polymer melt or dry blended with the polymer material prior to plasticizing or melting. The foamable gel is typically cooled to a lower foaming temperature to optimize desired physical characteristics of the foam. The gel may be cooled in the extruder or other mixing device or in separate coolers. The foaming temperature must be high enough to allow formation of the open-cell structure but low enough to prevent foam collapse upon extrusion. Desirable foaming temperatures range from about 105°C to about 160°C and preferably from about 120°C to about 135°C. The gel is then extruded or conveyed through a die of desired shape to a zone of reduced or lower pressure to form the foam. The zone of lower pressure is at a pressure lower than that in which the foamable gel is maintained prior to extrusion through the die. The lower pressure may be superatmospheric or subatmospheric (evacuated or vacuum), but is preferably at an atmospheric level. Other methods for making foams such as extruded foams of coalesced strand configuration, or open channel or perforated foams may also be utilized, if desired.

Open cell polyurethane and polyisocyanurate foams can be utilized and prepared, for example, as described in USPs 3,580,869; 4,795,763; 5,260,344; 5,288,766;

5,334,624; and 5,346,928, the relevant teachings of which are incorporated herein by reference.

Aerogels may comprise any of a variety of materials such as silica, metal oxides, carbon, and formaldehyde derivatives. Teachings to aerogels and methods of making are found in USPs 5,081,163; 5,242,647; 5,275,796; 5,358,802; 5,381,149; and 5,395,805, the relevant teachings of which are incorporated herein by reference.

Microcellular thermoplastic foams may be lightly cross-linked or non-crosslinked. The term "non-crosslinked" means the foam is substantially free of crosslinking. The term is inclusive however, of the slight degree of crosslinking which may occur naturally without the use of crosslinking agents or radiation. Non-crosslinked foams contain no more than 5 % gel per ASTM D-2765-84 Method A.

Useful foams include open-cell propylene polymer foams such as those taught in USPs 5,348,795 and 5,567,742, the relevant teachings of which are incorporated herein by reference. Useful propylene polymer foams include extruded coalesced strand foams, particularly those of ≥ about 50 %, preferably ≥ about 80 %, and most preferably ≥ about 95 open cell content.

Extruded coalesced strand foams are particularly useful because they can be evacuated more quickly than foams extruded from a conventional slit die or otherwise of a conventional unitary structure. Extruded coalesced strand foams define continuous channels between the strands extending the extrusion direction of the foam. The coalesced strands foam may be described as open channel or closed channel depending upon how closely packed the coalesced strands are. Open channel foams are those wherein a large proportion of the strand-to-strand interfaces define continuous channels which, on end or in cross-section, are visibly open to the unaided eye. Closed channel foams are those wherein a large proportion of the strand-to-strand interfaces define continuous channels which, on end or in cross-section, are visibly closed to the unaided eye. Closed channel foams exhibit faster evacuation times than foams of conventional unitary structure. Open channel foams exhibit faster evacuation times than foams of conventional unitary structure and closed channel foams. Evacuated insulation panels containing coalesced strand foams of either open channel and closed channel configuration are within the scope of the present invention. Strand foam

structures are described in USPs 4,824,720 and 5,124,097, the relevant teachings of which are incorporated herein by reference. Preferably, the primary source of evacuation or suction takes place directional with the continuous channels (extrusion direction) but may occur from any direction such as generally perpendicular to the direction of the continuous channels. Although use of a coalesced strand foam structure is preferred when continuous channels are desired, it is also within the scope of the present invention to introduce a plurality or multiplicity of channels into a foam of conventional unitary structure by perforating it partly through or entirely through with nails or needles or the like. Perforation of foam is taught in USP 5,585,058, the relevant teachings of which are hereby incorporated herein by reference.

In a preferred embodiment wherein the porous material is a foam, typical foams, when evacuated, provide an "R-value" or heat resistance on a per inch thickness basis of about 10 or more, preferably about 15 or more, and most preferably about 20 or more. "R-value" is the reciprocal of foam thermal conductivity times thickness as measured in units of (BTU x in.)/(hr. x ft^2 x °F). For instance, an evacuated foam having a thermal conductivity of 0.1 (BTU x in.)/(hr. x ft^2 x °F) (0.0144 Watts/meter K) has an R-value of 10. The above R-values are initial R-values rather than aged R-values. The thermal conductivity may be measured according to ASTM method No. C-518-91 at 40°F(4°C) temperature intervals with a mean temperature of 75°F (24°c).

The foam may be of any cell size, but microcellular cell sizes are preferred for their superior insulating performance. Cell sizes or pore sizes are measured according to ASTM D3576-77 except that measurement is taken from an enlarged photograph obtained by scanning electron microscopy (SEM) instead of measurement taken directly from the foam. Microcellular foams have an average cell size of about 70 micrometers (μm) or less (≤), preferably from about 5 to about 30 μm, more preferably, from about 1 to about 30 μm.

The foam preferably has the density ≥ 16 kg/m^3, more preferably ≥ 25 kg/m^3, and most preferably ≥ 100 kg/m^3; but is preferably ≤ 250 kg/m^3, more preferably ≤ than 200 kg/m^3, and most preferably ≤ 150 kg/m^3, according to ASTM D-1622-88.

When a polymer foam is employed as the porous material, the foam may be compressed to a thickness of from about 30 to about 95 % of its initial thickness or volume to

enhance heat insulating capability or a per unit thickness basis, or to enhance its long-term dimensional stability. Compressed foams are taught in WO 97/27986, the relevant teachings of which are hereby incorporated herein by reference. WO 97/27986, the relevant teachings of which are incorporated herein by reference, provides guidance related to compression and simultaneous compression and heating. The skin layer of the foam may also be skived off or planed off to better expose the open cell structure of the foam.

The receptacle or enclosure of the evacuated article may be formed of any flexible foil, film, or metallized film material having a sufficiently low permeability to permit the receptacle, upon evacuation to a pressure of < 10 torr (13 millibars (mbar)), to maintain a reduced pressure for a desired length of time. One embodiment of an evacuated article employs a receptacle in the shape of a generally flat, two-sided bag formed of a three-layer laminate film. The outer layer of the film comprises a scratch resistant material such as a polyester or a nylon. A middle layer is a barrier material such as aluminum, polyvinylidine chloride, or polyvinyl alcohol. The barrier material may be in the form of a separately applied foil or film or, in the case of a metal, may be applied by vapor deposition. The interior layer comprises a heat sealable material such as polyethylene or ethylene/acrylic acid copolymer. Additional teachings are seen in USPs 5,346,928 and 5,627,219, the relevant teachings of which are hereby incorporated herein by reference.

Evacuated articles may be formed as follows: a) place the support(s) inside a receptacle or enclosure such as a bag capable of being made air tight or hermetically sealed; b) evacuate the interior of the receptacle or enclosure and the foam to a partial or near total vacuum; and c) seal the receptacle or enclosure to be air tight or hermetically sealed. The interior of the evacuated or vacuum article is evacuated to ≤ about 10 torr, more preferably to ≤ about 1 torr, and most preferably to ≤ about 0.1 torr absolute pressure. In the preferred foams using densities, and cell sizes referred to above, the foam may be sufficiently insulating to avoid a requirement the additional use of any radiation attenuating additives or "getter" materials in making the support to achieve the desired insulating properties. However, if desired, an infrared attenuating agent (IAA) may be incorporated into the porous support to reduce the amount of infrared radiation which may travel through the support. It may be an infrared reflecting or absorbing substance or both. The IAA is composed of a different substance than the substrate of the foam in which it is hereby incorporated. Useful IAA

include iron oxide, titanium dioxide, particulate metals such as aluminum, silver, and gold, and carbonaceous substances such as carbon black, activated carbon black, and graphite. Useful carbon blacks include thermal black, furnace black, acetylene black, and channel black. Useful graphites are natural graphite and synthetic graphite. Preferred IAA are carbon black and graphite. The IAA preferably comprises between about 1.0 and about 20 wt%, more preferably between about 1.0 to about 10 wt%, and most preferably between about 2 wt% and about 7 wt%, based upon the weight of the polymer material. In the case of carbon black and graphite, it is desirable to use particles of a size which achieve a high degree of dispersion in the foam.

To further enhance the long-term performance of the vacuum article, the evacuated interior of the support may also include a "getter" material. The getter material adsorbs gases and/or vapors which may seep or permeate into the insulation article over time, or which remain inside the article after evacuation. Conventional getter materials include metal and metal alloys of barium, aluminum, magnesium, calcium, iron, nickel, and vanadium. Teachings to suitable getter materials include but are not limited to those set forth in USPs 5,191,980; 5,312,606; 5,312,607; and WO 93/25843, the relevant teachings of which are incorporated herein by reference.

Other types of useful getter materials include conventional desiccants, which are useful for absorbing water vapor or moisture. Such materials are advantageously incorporated into the evacuated insulation article in the form of a packet having a porous or permeable wrapper or receptacle containing the material therein. Useful materials include silica gel, activated alumina, activated carbon, aluminum-rich zeolites, calcium chloride, calcium oxide, and calcium sulfate. A preferred material is calcium oxide.

USP 5,858,501, the relevant teachings of which are hereby incorporated by reference, describes a means to obtain an evacuated article free of wrinkling, by providing a foam core having indentations therein. Preferably one or both of the one or more porous or open-celled rigid material matrixes and the one or more plates have a plurality of indentations.

In one embodiment, one or more rigid insulating plates having indentations therein may be placed at one or more surfaces of a foam within an evacuated insulation article. The use of plates inside a vacuum article, or outside a vacuum insulation article, shields low

melting point porous materials from transient heat exposure, such as may be experienced during the foaming of polyurethane foam around a vacuum insulation article during the construction of an appliance. The indentations can take the form, pattern, and dimensions described above for indentations within the foam. The article can be assembled as described above except that one or more plates are inserted within the deformable receptacle along with the foam. For a typical rectangular or square article, plates will typically be situated at the two major surfaces of the support. The plate or plates can be made of any natural or synthetic material (e.g. metals, wood, or plastic) that is chemically inert to the porous support and the receptacle, as long as it has sufficient rigidity to resist deformation during evacuation. Upon evacuation of the support and shrinkage of the foam, the deformable receptacle will conform to the shape of the support and rest substantially within the indentations of the plate or plates.

Optionally, the exterior portion of the insulation article may be protected from punctures by covering it with cushion material or rigid facers to protect the physical integrity of the article and its hermetic seal.

A wide variety of temperature-sensitive components may be protected by means of this invention, including insulated automotive components such as an insulated battery, power distribution center, fuse support, relay enclosure, computer or communication device. Components of particular interest include batteries, computers and a communication devices. A particularly useful embodiment is an insulated automotive battery, especially where the component is a lead acid battery and the engine compartment is an automobile engine compartment. Other applications or particular interest include insulation for household appliances such as refrigerators, freezers, or ovens, and for shipping containers for temperature-sensitive items.

WHAT IS CLAIMED IS:

1. An evacuated insulation article comprising at least two rigid porous side supports enclosed in a single deformable evacuated receptacle, wherein at least two adjacent side supports form a corner having an angle of less than 150 degrees, and the supports are shaped or are spaced apart sufficiently within the receptacle before evacuation so that (i) the supports form the corner upon evacuation of the receptacle or (ii) the corner is formed after evacuation by bending the receptacle between the supports, without causing tears or breaks in the receptacle.

2. An evacuated insulation article having at least one rigid porous side support enclosed in a single deformable evacuated receptacle, wherein the support has at least one flexible groove which may bend and form a corner having an angle of less than 150 degrees, without causing tears or breaks in the receptacle.

3. An evacuated insulation article having at least two rigid porous side supports enclosed in a single deformable evacuated receptacle, the side supports having shaped edges which form joints where they contact each other, and wherein the length of the joint is at least 120 percent of the thickness of the supports.

4. A multi-sided evacuated insulation article comprised of at least three evacuated receptacles, each of which is in contact with at least one other receptacle, each of which contains a rigid porous side support having a shaped edge, wherein the edges of the receptacles define a joint where they contact each other, and the supports are shaped along their edges so that the length of the joint is at least 120 percent of the thickness of the supports.

5. The article of any of claims 1 – 4, wherein the rigid porous side supports have a density in the range of from 16 kg/m^3 to 250 kg/m^3 and are comprised of a polymer foam.

6. The article of claim 5 wherein the rigid porous side supports are comprised of polystyrene foam.

7. The article of claim 6 wherein the polystyrene foam has an average cell size in the range of from 1 to 70 micrometers and an open cell content of at least 50 percent.

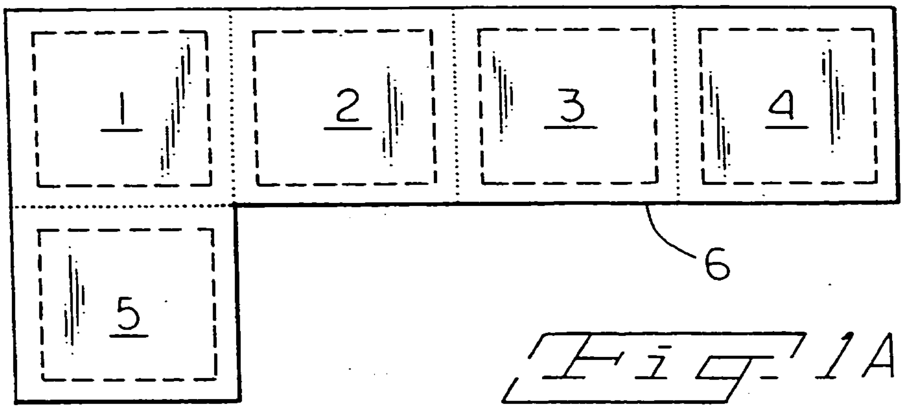

Fig. 1A

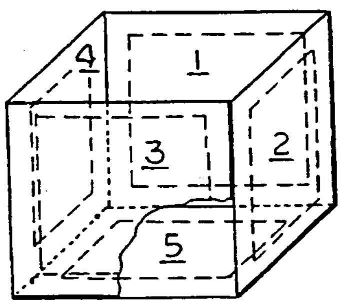

Fig. 1B

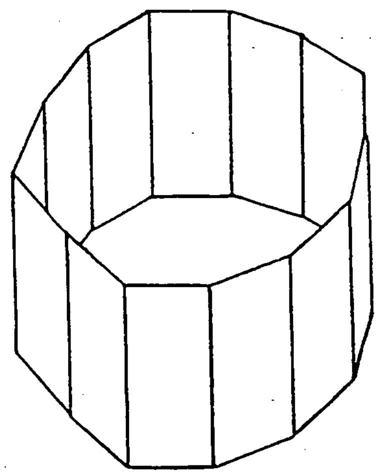

Fig. 2B

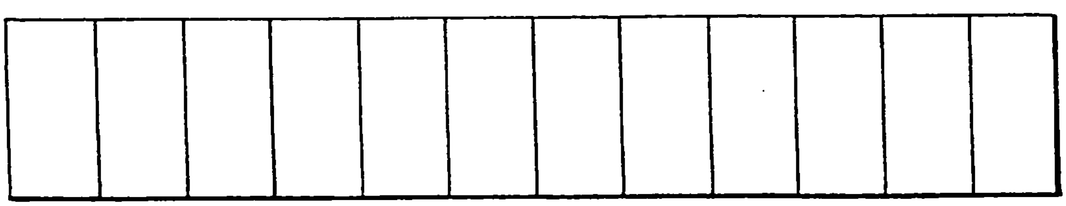

Fig. 2A

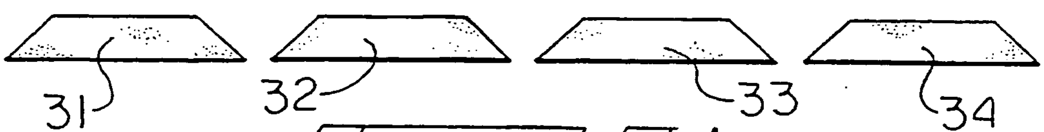

Fig. 3A

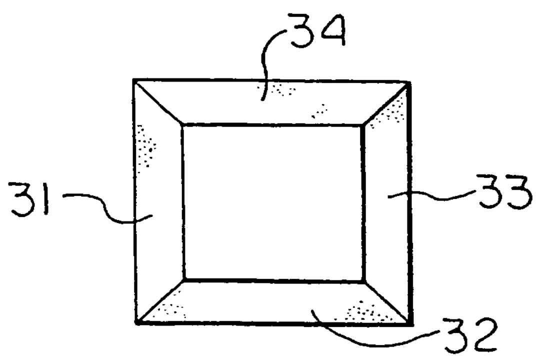

Fig. 3B

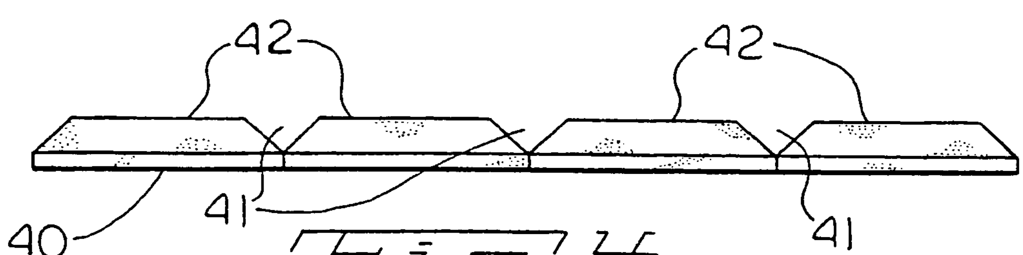

Fig. 4

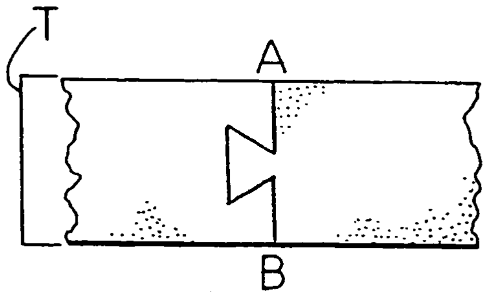

Fig. 5A

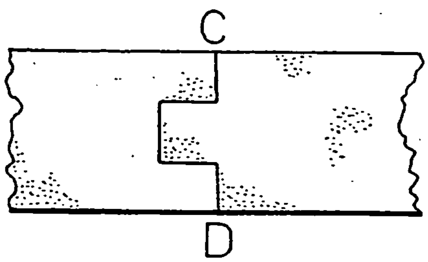

Fig. 5B

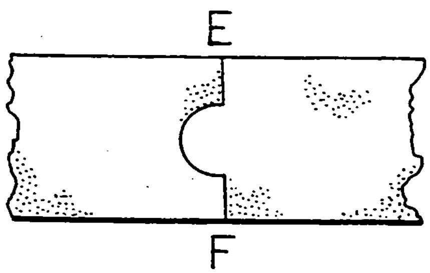

Fig. 5C

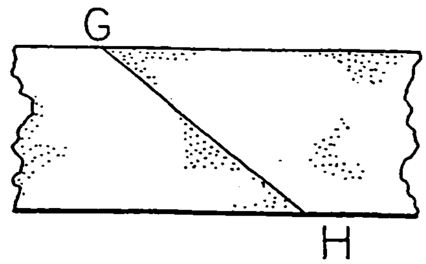

Fig. 5D

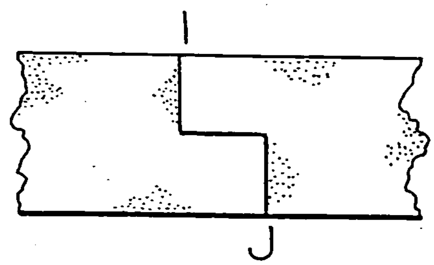

Fig. 5E

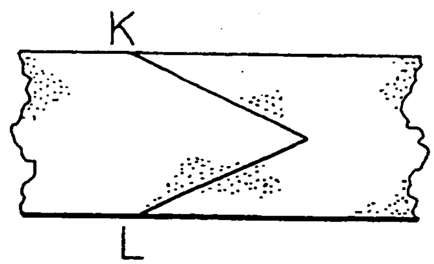

Fig. 5F

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/15007

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16L59/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	WO 99 23374 A (HAMEDANI MOHAMMAD F) 14 May 1999 (1999-05-14) claim 20; figures	1-4,6 5
X	US 5 273 801 A (KIRBY DAVID B ET AL) 28 December 1993 (1993-12-28) claim 1; figures 9,10	1-4
X	WO 96 32605 A (ICI PLC) 17 October 1996 (1996-10-17) abstract; claims 1-3; figures	2

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 September 2000	18/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Budtz-Olsen, A

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 00/15007

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
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